Santos and Santos *Crime Sci (2015) 4:27*
DOI 10.1186/s40163-015-0041-6

Crime Science
a SpringerOpen Journal

RESEARCH Open Access

Examination of police dosage in residential burglary and residential theft from vehicle micro-time hot spots

Rachel B. Santos[1*] and Roberto G. Santos[2]

Abstract

Rooted in the near repeat phenomenon and police crime analysis, a crime "flare up" or micro-time hot spot is the emergence of several closely-related crimes within a few minutes' travel distance from one another. It occurs within 1–2 weeks and can last several weeks or months before running its course and cooling down. A micro-time hot spot is a type of crime pattern identified by police crime analysts to guide short-term police response, particularly directed patrol. Published work by these authors has examined a subset of the 5 years of data to test the effectiveness of the Port St. Lucie, FL Police Department's response to micro-time hot spots. Those quasi-experimental studies found separately for burglary and theft from vehicle occurring in residential areas that micro-time hot spots receiving police response had nearly 20 % fewer subsequent crimes than those receiving no police response. This study examines all 121 residential burglary and 163 residential theft from vehicle micro-time hot spots receiving police response to understand how two factors of police response dosage (i.e., the amount of directed patrol and how quickly directed patrol is deployed) are related to the amount of subsequent crime. Separate negative binominal analyses for each crime type showed that more directed patrols per day were related to lower levels of subsequent crime for both crime types, and a quicker response was related to lower crime for residential theft from vehicle. That is, the more and quicker the response, the quicker resolution and cooling off of the micro-time hot spot. The findings were stronger for residential burglary, and a visual examination of first standard deviation confident intervals of directed patrol rate by crime suggests that between four and six directed patrols per day in residential burglary micro-time hot spots was optimal. Although the data are from one police agency, these promising results support future research and provide guidance to police for implementing directed patrol in short-term hot spots of property crime.

Keywords: Micro-time hot spot, Directed patrol, Police response dosage, Property crime, Crime analysis, Crime patterns

Background

Over the last 30 years, criminology of place research and a significant number of studies on the effectiveness of police crime prevention strategies in places have focused primarily on long-term hot spots which are areas with disproportionate amounts of crime compared to other areas over one to several years (Braga et al. 2014; Weisburd et al. 2012). More recently, a large body of crime science research has also found and confirmed that crime incidents also cluster in the short-term. This field is called near repeat victimization and occurs when non-victimized places near places that have been victimized are themselves victimized within a short time frame (Johnson et al. 2007, 2009; Sagovsky and Johnson 2007). In police practice, crime analysts systematically identify both long and short-term hot spots. These short-term geographic clusters of crime are called "crime pattern hot spots" by police (Santos 2012) and are used to guide police in their short-term crime reduction efforts (Austin et al. 1973; Booth 1979; Chang et al. 1979; O'Shea and Nicholls 2003; Paulsen et al.

*Correspondence: rboba@fau.edu
[1] Criminology and Criminal Justice, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431, USA
Full list of author information is available at the end of the article

2009; Santos 2012; Santos and Taylor 2014). However, where there is a large body of research on long-term hot spots, there is little research on short-term clusters of crime and the effectiveness of police response to them (Santos 2014).

Consequently, this article examines micro-time hot spots and the effectiveness of police response, particularly directed patrol, in these areas. The micro-time hot spot is distinguished from a long-term or "macro-time" hot spot, as the emergence of several closely-related crime incidents within a few minutes travel distance from one another that occurs within 1–2 weeks (i.e., micro-time), in other words, a crime "flare up." Once the flare up occurs, it can either immediately dissipate or last for several weeks or months before running its course, cooling down, and ending on its own (Santos and Santos 2015a, b). Importantly, research has found that micro-time hot spots can occur within long-term, stable hot spots or separate from them (Gorr and Lee 2015; McLaughlin et al. 2007). Thus, research on the nature of micro-time hot spots and on the effectiveness of police response is warranted.

This study complements two previous quasi-experimental analyses of the Port St. Lucie, FL Police Department's systematic response to micro-time hot spots. Those findings indicated a 20 % reduction in both residential burglary and residential theft from vehicle crimes (i.e., theft from vehicles occurring in exclusively residential areas) when police responded in micro-time hot spots (Santos and Santos 2015a, b). Using the data from the same 5 years, this analysis uses negative binomial regression to closely examine 121 residential burglary and 163 residential theft from vehicle micro-time hot spots that received police response, specifically directed patrol, to understand the effect of response dosage on the reduction of crime.

There is a wide range of research on directed patrol in long-term hot spots (Braga et al. 2014), but there is much less research on response dosage (Groff et al. 2015; Telep et al. 2014). Koper (1995) asserts that 15 min is the optimal time for an officer to patrol within a long-term hot spot. Although there is some evidence as to how many times officers should patrol into each long-term hot spot (Telep et al. 2014), there is no evidence for short-term hot spots. It is logical that responding more times in a hot spot, whether long-term or short-term is more effective in reducing crime, but as the Koper (1995) study showed, there is a point of diminishing returns. This analysis examines how the level of directed patrol influences the number of subsequent crimes in the micro-time hot spot as well as offers a cursory look at what might be optimal for accelerating the cooling off of a micro-time hot spot.

In addition, this analysis examines the immediacy of response deployment; that is, how quickly the agency sends officers to conduct directed patrol after the micro-time hot spot is identified. In long-term, stable hot spots, the most effective crime reduction strategies are those that address underlying conditions of crime which often take months and often years to implement (Telep and Weisburd 2012; Weisburd et al. 2010). Therefore, the immediacy of these responses is not as important as a implementing a comprehensive long-term solution over a course of a few months. In contrast, micro-time hot spots flare up and cool down relatively quickly, so as a consequence, it may be particularly important to implement responses quickly for effective crime reduction. Thus, this study examines whether time between micro-time hot spot identification and police response is related to the speed in which the micro-time hot spot cools off.

In summary, since previous analyses using these data have shown that police response to micro-time hot spots reduced crime (Santos and Santos 2015a, b), the objective of this analysis is to examine to what extent the amount of directed patrol and the quickness of response deployment predict the amount of crime in the micro-time hot spot after it was identified. It is hypothesized that both response dosage factors will independently influence the amount of crime for burglary and theft from vehicle crime occurring within residential areas. That is, more directed patrol and quicker deployment will result in fewer crimes. A separate analysis is conducted for each crime type with the goal of providing (1) a better understanding of micro-time hot spots and (2) guidance for implementing directed patrol in short-term clusters of residential burglary and residential theft from vehicle.

The micro-time hot spot

The basis for understanding how and why micro-time hot spots is rooted in the phenomenon of near repeat victimization. Crime scientists have established that near repeat victimization exists for theft from vehicle and residential burglary crime and that it occurs rapidly (Bowers and Johnson 2005; Johnson and Bowers 2004; Townsley et al. 2003). For example, Sagovsky and Johnson (2007) found that most near repeat burglaries occur within 7 days of the original burglary, particularly within 24 h. Johnson et al. (2007) found that 28 % of all theft from vehicle near repeats occurred within 7 days, roughly 40 % within 14 days, and 50 % within 28 days.

Clearly differentiating micro-time hot spots from long-term hot spots is important for both research and

practice (Gorr and Lee 2015; McLaughlin et al. 2007; Santos and Taylor 2014). While both types are defined as several crimes occurring in relatively small geographic areas, the distinction lies in the temporal duration of the hot spot. Long-term hot spots are identified using between 6 and 12 months of crime incident data (Braga et al. 2014) and are stable (i.e., the same areas remain hot spots) year to year (Weisburd et al. 2012). On the other hand, micro-time hot spots are identified by examining 1–2 weeks of data and typically last for several weeks (Santos and Santos 2015a, b).

Micro-time hot spots do occur within stable, long-term hot spots as well as in other areas that are not accustomed to high levels of crime or have an ongoing crime problem. However, micro-time hot spots are not stable over time but flare up in one area and may not return to that same area for many months, years, or not at all. A study by Johnson et al. (2008) supports the idea that there are short-term clusters of crime occurring both within and separate from long-term clusters. Examining residential burglary and theft from vehicle data in 2-week intervals over 6 months, they found that in some areas, most 2-week periods had little risk of victimization, but there were 2-week periods in different areas with very high risk for crimes. The implication is that only identifying long-term hot spots with long-term data can create the misconception that crime is continuous (i.e., occurring on a regular basis vs in short-term clusters) and can overlook crime flare ups that occur in isolation (Gorr and Lee 2015; Johnson et al. 2008).

We provide an illustration of the evolution of a micro-time hot spot based on the criteria for identification used in this study: (1) two or more incidents of one crime type (i.e., residential burglary or residential theft from vehicle); (2) occurring from 1 to 14 days of another; (3) within a 0.50-mile radius (i.e., 0.79 square miles), and (4) considered "cooled off" once there were no more crimes for 21 days.[1] Figure 1 illustrates an example of how a micro-time hot spot flares up and cools off.

The left map shows a micro-time hot spot at initial identification with two crimes occurring inside a 0.10-mile radius within 4 days (i.e., February 1st to February 5th). In the middle map, additional crimes #3 and #4 occur and are part of the micro-time hot spot because they are located within a 0.25-mile radius of the mean center of the two original crimes and they occur 2 and 3 days later, respectively (i.e., within 21 days of the previous crime). The right map shows how the micro-time hot spot continues to flare up, since crime #6 falls inside the 0.25-mile radius and occurs only 7 days after crime #4. Crime #5 is not included in the micro-time hot spot because it does not fall within the maximum allowed 0.50-mile radius. The micro-time hot spot is considered cooled off after crime #6, since crime #7 occurred 25 days after crime #6. Therefore, in this illustration, the micro-time hot spot began with two crimes in a 0.10-mile radius over 4 days. It continued to "flare up" with three more crimes within a 0.25-mile radius and lasted 12 more days before "cooling off."

Importantly, it is possible that a new micro-time hot spot could develop around crime #5 in terms of space and #7 in terms of time, but they would each have to meet the criteria of a new micro-time hot spot (i.e., two crimes within 0.50 miles and 14 days). In other words, once a crime is part of a micro-time hot spot it cannot be part of a new one, and even though a micro-time hot spot may be close to another, it does not overlap in either time or space.

Police response to micro-time hot spots

A meta-analysis of research on police response in long-term hot spots finds that short-term police response—particularly increased directed patrol—is effective in reducing crime (Braga et al. 2014). Directed patrol is commonly used for long-term hot spots by police agencies around the United States as well as in the United Kingdom and Australia (Telep and Weisburd 2012). Closer examination of these results as well as findings from less rigorous hot spots studies show that the decreases in crime and calls for police service are primarily short term (Braga and Weisburd 2010), in that the effects tend to dissipate quickly after the intervention has ended (Braga et al. 2014). Telep and Weisburd (2012) recommend that long-term hot spots benefit most from identifying long-term solutions that seek to change the criminogenic characteristics and the built environment. Thus, it appears as though short-term responses, particularly directed patrol, that have a short-term effect in long-term hot spots might be better suited for "crime flare ups." In addition, the dynamic nature of micro-time hot spots makes it difficult to predict when and where they will flare up. Therefore, the goal of police response in micro-time hot spots is not to prevent a micro-time hot spot from developing but to shorten its duration once it is identified as an initial flare up.

[1] These criteria were developed by the Port St. Lucie, FL Police Department (PSLPD) based on the geography of the jurisdiction, the frequency of residential burglary and residential theft from vehicle crime in the city, as well as what is realistic for police response with the agency's available resources. The maximum radius used for identification was chosen by the police department was based on the city's size (i.e., over 115 square miles), the nature of zoning (i.e., most lots are 1/4 acre with single family homes), and what they felt was reasonable for patrol officers to respond to within a shift and their geographic areas of responsibility. Most of the micro-time hot spots were smaller than the maximum radius. Notably these criteria would be different for other jurisdictions. For example, one with more crime might increase the threshold of crime incidents, and one with an urban environment might decrease the radius.

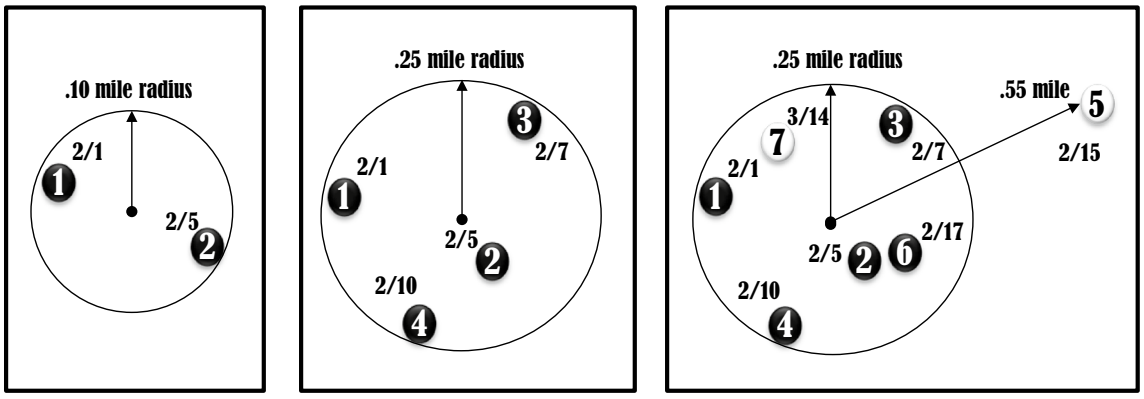

Fig. 1 Illustration of the micro-time hot spot

Methods

Agency background

The data for this study come from the city of Port St. Lucie, FL which is located in southeast Florida along the coast. The city grew over the last 25 years from a population of about 55,000 in 1990 to around 170,000 in 2015. Its UCR Part I Crime rate per 100,000 in 2013 was 1627. As of July 2015, there were 224 authorized sworn and 65 civilian positions in the Port St. Lucie Police Department. Micro-time hot spots represent the short-term units of response for the department's systematic crime reduction efforts, and none of the agency's efforts examined here (i.e., crime analysis or responses) were employed as "extra" resources or through the use of overtime but are a result of the standard practices of the agency.[2]

Micro-time hot spot data and variables

Because this study is an ex post facto examination of the police agency's practices over 5 years, 2008–2012, the researchers did not control how micro-time hot spots were identified nor how the police response was implemented. The systematic and consistent practices of this police agency created a unique opportunity for the quasi-experiments already conducted (Santos and Santos 2015a, b) as well as this study. The city is a suburban bedroom community with no major malls and very few large business plazas, so the police department identifies and responds primarily to property crime occurring in residential neighborhoods, specifically burglary and theft from vehicle. Micro-time hot spots of commercial burglaries or thefts from vehicles located in commercial areas occurred much less often and are not examined here because they represent distinctly different types of micro-time hot spots.

Throughout the 5 year period, the same two crime analysts used the following criteria discussed previously as the basis for identifying residential burglary and residential theft from vehicle micro-time hot spots: (1) two or more crimes; (2) occurring from 1 to 14 days of another; (3) within a 0.50-mile radius or 0.79 square miles, and (4) considered "cooled off" once there were no more crimes in the micro-time hot spot for 21 days. Once clusters of crimes were identified using these criteria, the crime analysts finalized the micro-time hot spots using standard crime pattern identification methodology (Gwinn et al. 2008; Santos 2012). Where repeat incidents are primarily identified by their crime type, geographic location, and date of occurrence, micro-time hot spots are also identified based on the following standards established by the International Association of Crime Analysts (2011: 1):

- [The crimes in the micro-time hot spot] share at least one commonality, such as the type of crime, behavior of the offenders or victims, characteristics of the offender(s), victims, or targets, the property taken, or the location type of occurrence.
- There is no known relationship between victim(s) and offender(s) (i.e., stranger-on-stranger crime) in any of the crimes.
- The shared commonalities make the set of crimes notable and distinct from other criminal activity occurring within the same general date range.

The Port St. Lucie Police Department's crime analysts monitored crime data on a daily basis both to identify

[2] The agency employs Stratified Policing (Santos and Santos 2015c) as its organizational framework for implementing evidence-based crime reduction strategies into the police organization's day-to-day practices by providing actionable crime analysis products and a foundation for the accountability of problem solving through a structured set of meetings (Boba and Santos 2011). The Port St. Lucie Police Department's approach has been successful as evidenced by a process and impact evaluation (Santos 2013), and this work has received a prestigious policing award, the International Association of Chiefs of Police Law Enforcement Research Award (International Association of Chiefs of Police 2010).

new micro-time hot spots as well as to detect new crimes in those already identified. To disseminate the micro-time hot spot for police response, the crime analysts produced a one-page bulletin that included information such as date, time, location, and method of the individual crimes, known theft from vehicle or residential burglary offenders that lived in the micro-time hot spot, field interview information, and whether evidence was collected at the scene (e.g., finger prints and DNA). A map was included that illustrated the locations of the crimes, field contacts, and known offender residences as well as a circle around the outermost crimes representing the radius of the micro-time hot spot. Once published and assigned for police response, the micro-time hot spots were tracked by the crime analysts until there were no more crimes within 21 days of the last crime occurring within a 0.50-mile radius.

The original database of all micro-time hot spots identified by the crime analysts from 2008 to 2012 contained 546 residential burglary and residential theft from vehicle micro-time hot spots—284 with response and 262 without response. In the two quasi-experimental tests of effectiveness, micro-time hot spots with high levels of response were matched to comparison cases (Santos and Santos 2015a, b), and 280 micro-time hot spots with and without responses were analyzed (i.e., 140 in each group). For the current study, only micro-time hot spots with response (N = 284) were examined in order to focus on the effect of response dosage. The following are five characteristics of the micro-time hot spots that were included as predictors in the negative binomial regression analyses[3]:

- *Initial radius: radius of the crimes (in miles) in the initial micro-time hot spot* On each bulletin, the analyst drew a circle on the map based on the exact locations of the outermost crimes and encompassed all the crimes within the micro-time hot spot and measured the radius of the circle. This variable is used as a control as it provides the relative size of the hot spots to one another when they are smaller than the maximum allowed radius (0.50 miles). The agency's stated policy was that officers were to patrol the area within the initial radius.
- *Targets: number of single and multi-family homes in the initial radius* This variable was created using aerial maps to count the number of single family and multi-family homes within the initial radius. This variable accounts for the specific differences in the number of potential residential targets within each micro-time hot spot for residential burglary and is a proxy for vehicles targeted for theft, as only those thefts from vehicle incidents occurring at residences were included in the analysis.
- *Initial crime: number of crimes in the micro-time hot spot when it is initially identified* According to the agency's policy, each micro-time hot spot had at least two crimes, but could have had more than two. This variable measures the relative intensity of the initial micro-time hot spot.
- *Initial time span: number of days between the first crime and the last crime in the initial micro-time hot spot* The initial time span provides the temporal scope of the micro-time hot spot when identified. This variable measures the temporal clustering of initial crimes within micro-time hot spot.
- *Known offenders: number of known residential burglary or theft from vehicle offenders who currently live within the initial radius* Crime analysts provided individuals' names and pictures on the bulletin as part of the agency's evidence-based policing response in which officers contact these individuals while responding in the micro-time hot spot. This was chosen by the agency since research on short-term clustering of crime finds burglars are more likely to commit crimes relatively close to where they live (Bernasco 2010).

The dependent variable—*subsequent crime*—is the number of crimes occurring after the micro-time hot spot was initially identified and before it cooled off based on the agency's criteria. In other words, it is the number of additional crimes occurring within a 0.50-mile radius of the center of the initial micro-time hot spot and within 21 days of the last crime occurring in the micro-time hot spot.

Police response data and variables

All individual crimes that occurred in the city and/or within each micro-time hot spot received a response from police which included a patrol officer responding to the home, taking a crime report, and doing a preliminary investigation. Depending on the evidence and nature of the crime, when appropriate, a detective conducted a follow up investigation. In terms of response to the micro-time hot spots, the agency mandated a minimum of 14 days of directed patrol after the bulletin was disseminated to officers. A micro-time spot was not considered "cooled off" until there were 21 consecutive days without

[3] Note that three additional control variables were used in the previous propensity score analysis—season (i.e., when the crimes occurred), district (i.e., where in the city crimes occurred), and the year in which the crimes occurred. They were not used in this analysis to achieve a better case to variable ratio in the multivariate analysis. Note in the previous analyses, none of these variables had meaningful impact on the dependent variable or other independent variables (Santos and Santos 2015a, b).

a crime, so the 14-day response was reinstated when appropriate.

While the police agency implemented responses including directed patrol, contacting potential victims, and contacting known offenders, the majority (94.8 %) of individual responses (17,925 of 18,856) were directed patrols, so only those are examined. A directed patrol included an officer driving into the micro-time hot spot and either being stationary in his/her vehicle or driving around in the micro-time hot spot area for around 15 min each time. All patrol officers working in the area of an active micro-time hot spot would respond as many times as possible along with their normal patrol duties. Officers recorded their directed patrol activities in an Intranet database while on shift. These data were used to classify and count the individual responses.

The first response dosage variable is the directed patrol rate. This is the number of individual directed patrols divided by the total number of days of the response for that micro-time hot spot (i.e., response span). A directed patrol rate implies that the patrols were implemented consistently throughout the response span. Since they were not, this is a limitation of this measurement. However, this measure does provide the relative intensity of the overall response to each micro-time hot spot since the response span also varied.

The second response dosage variable is how quickly the agency deployed officers into the micro-time hot spot after it was identified by the crime analysts. The variable, days to response, is the number of days between the publication of the bulletin and the first directed patrol. A value of zero was assigned to patrols implemented the same day as the bulletin was distributed. The agency mandated that responses occur immediately, but this did not always happen in practice which provides an opportunity to examine the effect of the quickness of the response on subsequent crime.

Results and discussion

Although both crime types are property crime occurring in residential areas, each crime type was analyzed separately by the crime analysts, and initial examination of the agency's response to each type of micro-time hot spot indicated they were different enough to warrant separate analyses of the effect of response dosage on subsequent crimes for this study. Table 1 presents the descriptive statistics for the eight variables by crime type. To examine the differences between the means by crime type, independent *t* tests were conducted. Six of the eight variables were significantly different at the 0.05 level which supports conducting separate negative binomial regression analyses by crime type.

For both crimes, in terms of the micro-time hot spot independent variables, when initially identified, micro-time hot spots had at least two crimes that occurred in no more than 14 days which adheres to the agency's identification criteria. On average, both types of micro-time hot spots had between three and four crimes occurring in 6–7 days. At identification, residential burglary micro-time hot spots had significantly larger radii (0.30 vs 0.25 mile; t-value 3.49; SE 0.02) and significantly more targets (871 vs 706; t-value 3.28; SE 50.15). There were between zero and four known offenders for both types, but residential theft from vehicle micro-time hot spots had significantly more known offenders on the bulletins with a mean of almost two versus only one for residential burglary (t-value −4.68; SE 0.17).

In terms of the independent variables related to response dosage, 3.51 directed patrols per day were implemented in residential burglary micro-time hot spots which was significantly lower than 3.92 per day, the amount implemented in residential theft from vehicle micro-time hot spots (t-value −2.03; SE 0.21). The agency deployed officers similarly for both crime types either on the same or next day after the bulletin was published but

Table 1 Descriptive statistics for all variables by crime type

	Residential burglary = 121				Theft from vehicle = 163			
	Minimum–maximum	Range	Median	Mean (SD)	Minimum–maximum	Range	Median	Mean (SD)
Initial crime	2–7	5	3.00	3.46 (1.15)	2–8	6	3.00	3.54 (1.21)
Initial time span*	1–14	13	7.00	6.63 (3.86)	1–14	13	5.00	5.68 (3.94)
Initial radius**	0.06–0.50	0.44	0.30	0.30 (0.13)	0.05–0.50	0.45	0.25	0.25 (0.13)
Targets**	146–1986	1840	852.00	871.53 (440.02)	102–1864	1762	653.00	706.90 (400.70)
Known offenders***	0–4	4	0.00	0.99 (1.34)	0–4	4	2.00	1.78 (1.45)
Directed patrol rate*	0.71–6.64	5.93	4.25	3.51 (1.59)	0.71–6.68	6.15	4.85	3.92 (1.81)
Days to response	0–2	2	1.00	0.74 (0.69)	0–2	2	1.00	0.83 (0.73)
Subsequent crime (DV)**	0–6	6	2.00	1.81 (1.53)	0–8	8	2.00	2.36 (1.71)

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (2-tailed independent *t* test results)

no later than 2 days after. Not shown in the table, the minimum length of the overall response for both crimes was 14 days which also adheres to the 14-day response required by the agency.

Lastly, the dependent variable—amount crime occurring after the identification of the micro-time hot spot [i.e., subsequent crime (DV)]—ranged from zero to six crimes for residential burglary micro-time hot spots and zero to eight crimes for residential theft from vehicle micro-time hot spots. The averages of 1.81 and 2.36 were significantly different (t-value −2.79; SE 0.20) showing that although both types have a similar number of initial crimes when identified, residential theft from vehicle micro-time hot spots have more subsequent crimes.

Table 2 depicts the correlation results for the independent and dependent variables also separated by crime type. Because all but one of the variables had discrete values with limited ranges, Spearman correlation was used in all but one test. The exception was a Pearson correlation test between initial radius, a continuous variable, and targets, a variable with a large range, which is highlighted in bold italic.

The results for residential burglary show that while some of the correlations are significant at the 0.05 and 0.01 levels, all but one are weak and fall below ±0.34. For residential theft from vehicle, the coefficients are stronger correlations and more are significant, but again, all but one are lower than ±0.39. For both types of micro-time hot spots, these results do not indicate a concern for multicollinearity (Field 2009), so these variables are included in the final analysis for each crime type.

The one exception for both types of crime is the Pearson coefficient result of 0.85 and 0.80, respectively, between initial radius and targets, which are significant at the 0.001 level. The targets variable is a count of the homes within the initial radius of the micro-time hot spot, and the city is homogenous in its residential lot sizes and zoning, so it is not surprising that the two variables are highly correlated. To avoid multicollinearity, only initial radius was used in the negative binomial regression analyses since it is the area designated for each response by the agency.

The dependent variable correlation tests with the independent variables resulted in slightly different results by crime type. For residential burglary, three of the six coefficients were significant where for residential theft from vehicle all six were significant. All but one coefficient for both crimes was below ±0.54 and the relationships were in the same direction for each pairing. The exception is the relationship between subsequent crime and directed patrol rate for residential burglary which resulted in a strong significant correlation of −0.77. The same test for residential theft from vehicle resulted in a correlation of −0.47 which is also significant but much weaker. These findings both support the further examination of these bivariate relationships with multivariate analysis as well as support separating the two types of crimes to reveal additional relationships for each type of micro-time hot spot.

Because the dependent variable is a discrete count variable instead of a rate, negative binomial regression was used for the analyses (Hilbe 2011), as it has been for other studies that employ crime counts as the dependent variable (Newton et al. 2014; Tompson and Bowers

Table 2 Correlations of all variables by crime type

N = 284	Targets	Radius	Initial crime	Directed patrol rate	Days to response	Subsequent crime (DV)
Residential burglary N = 121						
Initial time span	0.31**	0.29**	−0.00	0.11	0.18*	−0.04
Targets		***0.85******	0.31**	−0.08	0.15	0.08
Initial radius			0.23*	−0.01	0.13	0.16
Initial crime				−0.24*	0.18*	0.28**
Directed patrol rate					−0.21*	−0.77***
Subsequent crime (DV)					0.34***	
Theft from vehicle N = 163						
Initial time span	0.24**	0.32***	0.34***	−0.05	0.19*	0.23**
Targets		***0.80*****	0.39***	−0.26**	0.30***	0.43***
Initial radius			0.29***	−0.26**	0.34***	0.54***
Initial crime				−0.10	0.13	0.24**
Directed patrol rate					−0.20**	−0.47***
Subsequent crime					0.48***	

Bold italic indicates Pearson correlation tests; all others are Spearman tests

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ (2-tailed)

2012). Analysis of the dependent variable's distribution showed skewness and overdispersion evidenced in the variance (2.74) being greater than the mean (2.12). This also supports using negative binomial regression over other regression methods (Hilbe 2011).

Two similar models were constructed for each crime type. As noted previously, the initial radius and targets variables were highly correlated for both crime types, so only initial radius was included in the models.[4] The dependent variable, subsequent crime, was regressed against two response variables—directed patrol rate and days to response—and four micro-time hot spot variables—initial radius, initial crime, initial time span, and known offenders. Table 3 illustrates the results of the two models that examined 121 residential burglary micro-time hot spots and 163 residential theft from vehicle micro-time hot spots.

Comparing the results of both models, the log likelihood, Akaike Information Criteria (AIC) and Bayesian Information Criteria (BIC) scores show that the residential burglary model was a better predictor of subsequent crime than the residential theft from vehicle model (Hilbe 2011). The results also show differences in predictor variables in both the number and level of significance between the two models. For residential burglary, the strongest predictor was directed patrol rate which is negatively related to the dependent variable and significant at the 0.001 level. This indicates that the more directed patrols per day, the fewer subsequent residential burglaries. Initial radius was significant at the 0.05 level and positively related to the dependent variable. The results show that the smaller the initial radius, the fewer subsequent residential burglaries occurred.

Results of the residential theft from vehicle model yield these two significant relationships as well but in reverse order. The strongest predictor was initial radius significant at the 0.001 level with directed patrol rate significant at the 0.01 level. In this model, days to respond was significant at the 0.05 level in that the more days it took for the police to respond, the more subsequent residential theft from vehicle crime occurred.

For both crime types, directed patrol rate and initial radius are important predictors. For a more straightforward interpretation and comparison of the impact of the variables across models, the incidence rate ratios are provided which estimate the change in the rate of the dependent variable by each independent variable. Directed patrol rate was negatively related to subsequent crime, and the IIR indicates that one additional patrol per day is expected to result in a 36 % decrease in residential burglaries and a 16 % decrease in residential thefts from vehicles.

For initial radius, the measurement is in miles, so an increase by one mile is expected to increase residential burglaries 7.37 times and residential theft from vehicle 20 times. The interpretation of this relationship must consider the fact that the initial radius is dictated by the geographic criterion for both the identification and continuation of the micro-time hot spot. That is, no matter the size of the initial radius, each micro-time hot spot has essentially the same potential radius in which the subsequent crimes can occur—a maximum of 0.50 miles. Even if a micro-time hot spot begins with two crimes that are relatively close together (e.g., 0.10-mile radius) or far apart (e.g., 0.50-mile radius), the criterion allows that any subsequent crime (i.e., the dependent variable) can happen within a distance of up to 0.50-mile radius around the initial radius. Thus, the significant relationship here indicates that the smaller the radius at initial identification, the fewer subsequent crimes within a 0.50-mile radius, not within the area of the initial radius.

Lastly, days to response was only significant in the residential theft from vehicle model. The IIR of 1.38 indicates that for every day that the response is delayed, there is an expected 38 % increase in subsequent crime, and conversely, responding more quickly by 1 day is expected to decrease subsequent crime by 27.5 % (i.e., 1.00–1/1.37). Notably, while this variable is not significant for residential burglary, the IIR value of 1.33 had a p value of 0.10. This value is very close to the corresponding value in the residential theft from vehicle model and results in a decrease of 24.8 % (i.e., 1.00–1/1.33) when calculated similarly. Table 1 showed that the range of this variable for both types was 0–2 days. The ideal deployment of resources is on the same day as the bulletin (i.e., zero), so the difference between responding right away and waiting for 2 days is expected to result in 76 % more subsequent residential theft from vehicle crime.

Based on the goodness-of-fit measures, the residential burglary model proves to be stronger. The directed patrol rate variable is also much stronger for residential burglary so additional analysis of this variable was conducted focusing on residential burglary micro-time hot spots. Figure 2 presents a visualization of the mean and the first standard deviation confidence intervals. That is, the residential burglary micro-time hot spots were broken down into six groups based on the number of subsequent crimes that occurred (e.g., no more crimes, one more crime, two more crimes, etc.). The means and standard deviations were computed for each group separately and the mean and first standard deviation intervals are presented in Fig. 2.

[4] Two models not show here were conducted with the targets variable replacing radius. Comparison of the overall goodness-of-fit measures revealed few differences. In both models, there were no changes in the significant predictors' coefficients and their significance except that for residential burglary where radius was significant at the 0.05 level, targets was not significant and had a p value of 0.11. For theft from vehicle, radius and targets were significant similarly.

Table 3 Negative binomial regression results by crime type

	Residential burglary				Theft from vehicle			
	B	SE	Sign.	IRR	B	SE	Sign.	IRR
Directed patrol rate	−0.45	0.09	***	0.64	−0.17	0.06	**	0.84
Days to response	0.29	0.17	–	1.33	0.32	0.14	*	1.38
Initial radius	2.00	1.02	*	7.37	3.00	0.86	***	20.00
Initial crime	0.07	0.11	–	1.07	0.04	0.09	–	1.05
Initial time span	0.00	0.03	–	1.00	0.00	0.03	–	1.00
Known offenders	0.00	0.09	–	1.00	0.07	0.07	–	1.07
Intercept	0.84	0.62		2.31	0.06	0.43		1.06
Log likelihood	−201.44				−315.12			
AIC	416.89				644.25			
BIC	436.46				665.91			
N	121				163			
df	114				156			

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

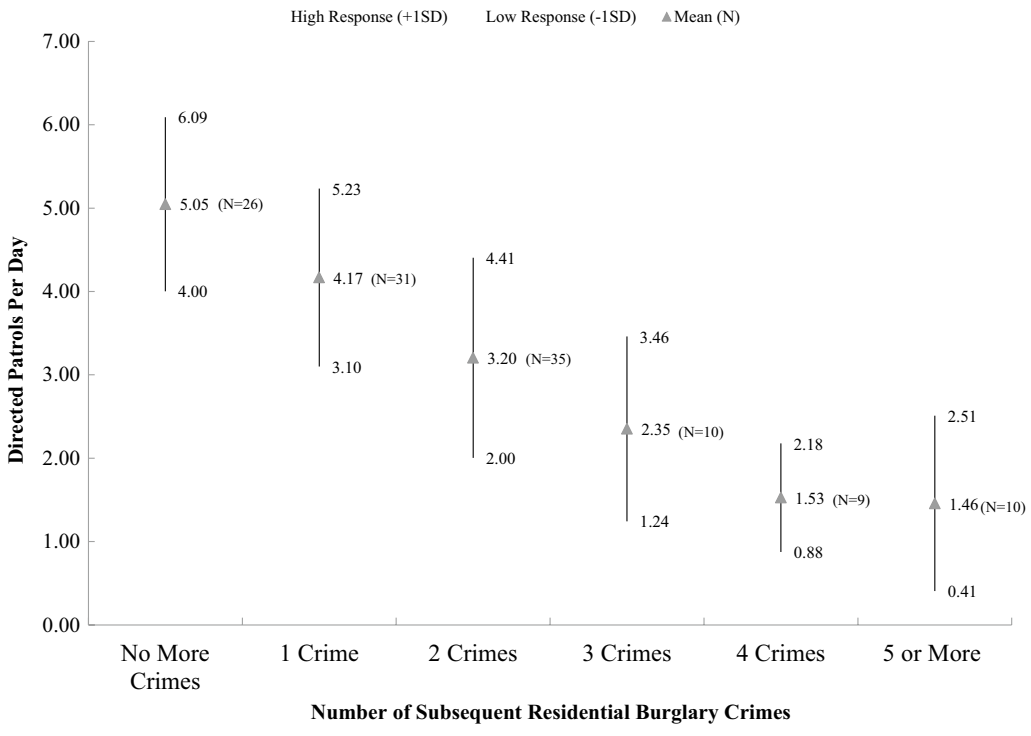

Fig. 2 Analysis of mean and standard deviation intervals: directed patrol rate for residential burglary

The figure illustrates that the 26 micro-time hot spots with no subsequent crimes had an average of around five directed patrols per day and 68 % had between four and six directed patrols per day. For the 31 micro-time hot spots with one subsequent crime, 68 % had between three and five responses. Overall, the figure corresponds to the regression results in that as the directed patrols increase, the subsequent crimes decrease and the illustration suggests that the optimal number of directed patrols per day is between four and six responses per day.

Conclusions

Two previous quasi-experimental studies using a subset of these data showed that the agency's response to micro-time hot spots was effective and reduced subsequent crime (Santos and Santos 2015a, b). This study

has sought to examine how responses dosage was related to crime reduction. The data used for these studies was collected after the fact, so the criteria used for identifying micro-time hot spots and for implementing the police response was determined by the police agency itself and not by the researchers. However, these criteria were implemented consistently over 5 years with systematic accountability and data collection in place, which provided an extraordinary opportunity to examine police response to short-term crime flare ups.

This study's findings add to both the evidence on the short-term hot spot phenomenon as well as police response within this type of hot spot. The first finding is that micro-time hot spots exist as clusters of near repeats. The fact that the police crime analysts were able to identify micro-time hot spots of two different crime types—residential burglary and residential theft from vehicle—over a long period of time (5 years) is evidence that the theoretical micro-time hot spot can be operationalized in practice. This result is important because while research has found that police crime analysts have been identifying crime pattern hot spots for decades (Austin et al. 1973; Booth 1979; Chang et al. 1979; Paulsen et al. 2009; Santos 2012), very little research has examined this practice closely.

The results of the descriptive statistics and correlation analysis show that the characteristics of residential burglary and residential theft from vehicle micro-time hot spots as well as how the police responded to them were similar. This supported conducting parallel and separate negative binomial regression analysis on the two crime types. The results of both analyses support the original hypotheses of this study that more directed patrol will result in fewer subsequent crimes. Although the residential burglary results were nearly significant, only the residential theft from vehicle results showed that quicker deployment of resources in micro-time hot spots results in fewer subsequent crimes.

The implications of these two findings are that police can accelerate the "cooling off" of the micro-time hot spot by responding immediately and with directed patrol. In particular, directed patrol had a stronger effect for residential burglary micro-time hot spots and showed that one additional directed patrol per day is expected to result in 36 % less subsequent residential burglaries and 16 % less residential theft from vehicle crime. In addition, visualization of the means and standard deviation intervals suggest that for residential burglary between three and five directed patrols per day might be the optimum level of response. Future research should delve into the optimal response levels even further with more precise response data and a more sophisticated analysis.

Lastly, the results show that for both types of crime, and more significantly for residential theft from vehicle crime, the distance between the crimes at initial identification (i.e., radius) is important and that response to crimes identified closer together initially, results in fewer subsequent crimes. Specifically, the study found that for every reduction of 0.10 miles in the radius, there is an expected 8.6 % [i.e., $(1.00–1/7.37) \times 0.10$] and 9.5 % [i.e., $(1.00–1/20) \times 0.10$] subsequent crime in residential burglary and residential theft from vehicle micro-time hot spots, respectively. While this exact distance may not be applied in cities with different geography than Port St. Lucie, the implication of this finding is that crime analysts should use narrow spatial criteria (i.e., smaller maximum radius) for the initial identification of a micro-time hot spot. This finding supports research on near repeats of burglary and theft from vehicle that defines the phenomenon using narrow distances, such as crimes that occur at houses 300–400 m apart (Johnson and Bowers 2004; Johnson et al. 2007), at houses next to one another, or houses on the other side of the street (Bowers and Johnson 2005). The finding also supports criminology of place research that defines hot spots as relatively small "micro-places," such as clusters of addresses or street segments (Weisburd et al. 2012), as well as research on policing that concludes that more effective police strategies are more focused spatially (Telep and Weisburd 2012).

The main limitation of this study is that it examines data from only one agency. Thus, the research findings are not generalizable, and these findings should be interpreted with caution. Additional research in different jurisdictions with the same types of crimes is necessary to confirm these results; however, the lack of other research and the typical nature of this jurisdiction (i.e., suburban housing and average crime rate) examined make the findings practically relevant to police agencies that are currently looking to focus their short-term crime reduction efforts. Additional research might also examine burglary and theft from vehicle at commercial places and other types of crimes that cluster spatially in the short-term like auto theft and robbery.

Other limitations are related to the amount and type of data that was collected from the police agency. First, there were a relatively low number of cases for each crime type in the database (i.e., 121 for residential burglary and 163 for residential theft from vehicle) that limited the number of predictor variables that could be considered in the regression model. Having more micro-time hot spots in the database as well as more variables for consideration would improve the rigor of future analyses.

The data collected from officers about each directed patrol was also limited, and an analysis of the time spent on each patrol could was not conducted so we were unable to contribute evidence to research on the ideal level of time officers should patrol—for example, research on

the "Koper Curve" (Koper 1995). As noted earlier, the directed patrol rate variable used in the analysis did not allow the analysis of the distribution of directed patrols within each response span. Future research should collect and analyze the distribution of individual responses within the overall response span to determine if implementing more responses at the beginning of the response span is more effective than implementing them equally across the entire response span. Important research questions can be inferred from this study for which researchers can design the data collection and methodology in a way that overcomes the limitations.

Discussion of the study's findings at a broader level is also important for informing police crime reduction practice. For example, a decrease of two crimes in one micro-time hot spot does not seem practically meaningful for a police department seeking to reduce crime in an entire city. However, the results suggest that if a police agency systematically identifies and responds to micro-time hot spots, overall levels of crime can be impacted. For example, based on these results, if an agency implements 2–3 h of 15-min patrols each day over 2 weeks for 100 micro-time hot spots, 200 crimes could be prevented. Thus, if the 100 micro-time hot spots average seven crimes without a response, by responding, the agency could have prevented 200 of 700 crimes which would be a 28.5 % decrease.

In conclusion, there has been a recent call for "translational criminology" (Laub 2011) in which researchers interpret their findings into evidence-based policy related to crime, criminal justice, and crime prevention. This study has linked the phenomenon of near repeats to the police practice of crime pattern hot spot identification and has added evidence to the conversation about how police dosage is related to crime reduction in short-term clusters of residential burglary and residential theft from vehicle. These initial and encouraging findings provide support for continuing research in this area and indicates that police response to short-term crime flare ups can be worthwhile part of a police agencies' overall crime reduction efforts.

Authors' contributions

RGS collected the original data and conceived the overall approach and topic. Both RGS and RBS participated in the design, conceived the analysis, conducted statistics, and drafted the manuscript. All authors read and approved the final manuscript.

Author details

[1] Criminology and Criminal Justice, Florida Atlantic University, 777 Glades Road, Boca Raton, FL 33431, USA. [2] Port St. Lucie, FL Police Department, 121 SW Port St. Lucie Blvd, Port St. Lucie, FL 34984, USA.

Competing interests

The authors declare that they have no competing interests.

Received: 25 March 2015 Accepted: 7 October 2015
Published online: 14 October 2015

References

Austin, R., Cooper, G., Gagnon, D., Hodges, J., Martensen, K., & O'Neal, M. (1973). *Police crime analysis unit hand-book*. Washington, DC: National Institute of Law Enforcement and Criminal Justice.

Bernasco, W. (2010). Modeling micro-level crime location choice: Application of the discrete choice framework to crime at places. *Journal of Quantitative Criminology, 26*(1), 113–138.

Boba, R., & Santos, R. G. (2011). *A police organizational model for crime reduction: Institutionalizing problem solving, analysis, and accountability*. Washington, DC: Office of Community Oriented Policing Services.

Booth, W. L. (1979). Management function of a crime analysis unit. *Law and Order, 27*(5), 28–33.

Bowers, K. J., & Johnson, S. D. (2005). Domestic burglary repeats and space–time clusters: The dimensions of risk. *European Journal of Criminology, 2*, 67–92.

Braga, A. A., Papachristos, A. V., & Hureau, D. M. (2014). The effects of hot spots policing on crime: An updated systematic review and meta-analysis. *Justice Quarterly, 31*, 633–663.

Braga, A. A., & Weisburd, D. L. (2010). *Policing problem places: Crime hot spots and effective prevention*. New York, NY: Oxford University Press.

Chang, S. K., Simms, W. H., Makres, C. M., & Bodnar, A. (1979). *Crime analysis system support: Descriptive report of manual and automated crime analysis functions*. Washington, DC: National Criminal Justice Information and Statistics Service.

Field, A. (2009). *Discovering statistics using SPSS*. Thousand Oaks, CA: Sage.

Gorr, W., & Lee, Y. J. (2015). Early warning system for temporary hot spots. *Journal of Quantitative Criminology, 31*, 25–47.

Groff, E. R., Ratcliffe, J. H., Haberman, C. P., Sorg, E. T., Joyce, N. M., & Taylor, R. B. (2015). Does what police do at hot spots matter? The Philadelphia policing tactics experiment. *Criminology, 53*(1), 23–53.

Gwinn, S., Bruce, D., Cooper, J., & Hick, S. (2008). *Exploring crime analysis: Readings on essential skills*. Charleston, SC: BookSurge.

Hilbe, J. M. (2011). *Negative binomial regression*. New York: Cambridge University Press.

International Association of Chiefs of Police. (2010). *IACP/Sprint Excellence in Law Enforcement Research Award Program: Spotlighting the power and impact of law enforcement academic research partnerships*. Alexandria, VA: Author.

International Association of Crime Analysts. (2011). *Crime pattern definitions for tactical analysis (White Paper 2011-01)*. Overland Park, KS: International Association of Crime Analysts.

Johnson, S. D., & Bowers, K. J. (2004). The burglary as a clue to the future: The beginnings of prospective hot-spotting. *European Journal of Criminology, 1*, 237–255.

Johnson, S. D., Lab, S., & Bowers, K. J. (2008). Stable and fluid hot spots of crime: Differentiation and identification. *Built Environment, 34*(1), 32–46.

Johnson, S. D., Summers, L., & Pease, K. (2007). *Vehicle crime: Communicating spatial and temporal patterns*. London: Jill Dando Institute of Crime Science.

Johnson, S. D., Summers, L., & Pease, K. (2009). Offenders as forager: A direct test of the boost account of victimization. *Journal of Quantitative Criminology, 25*, 181–200.

Koper, C. S. (1995). Just enough police presence: Reducing crime and disorderly behavior by optimizing patrol time in crime hot spots. *Justice Quarterly, 12*, 649–672.

Laub, J. H. (2011). *Translational criminology.* National Institute of Justice. http://www.nij.gov/nij/about/speeches/translational-criminology-3-1-2011.htm. Accessed March 19, 2015.

McLaughlin, L., Johnson, S., Bowers, K., Birks, D., & Pease, K. (2007). Police perceptions of the long- and short-term spatial distribution of residential burglary. *International Journal of Police Science and Management, 9*, 99–111.

Newton, A., Partidge, H., & Gill, A. (2014). In and around: Identifying predictors of theft within and near to major mass underground transit systems. *Security Journal, 27*, 132–146.
O'Shea, T. C., & Nicholls, K. (2003). Police crime analysis: A survey of U.S. police departments with 100 or more sworn personnel. *Police Practice and Research, 4*, 233–250.
Paulsen, D. J., Bair, S., & Helms, D. (2009). *Tactical crime analysis: Research and investigation*. Boca Raton, FL: CRC Press.
Sagovsky, A., & Johnson, S. D. (2007). When does repeat burglary victimization occur? *Australian & New Zealand Journal of Criminology, 40*, 1–26.
Santos, R. B. (2012). *Crime analysis with crime mapping*. Thousand Oaks, CA: Sage.
Santos, R. B. (2013). Implementation of a police organizational model for crime reduction. *Policing: An International Journal of Police Strategies and Management, 32*, 295–311.
Santos, R. B. (2014). The effectiveness of crime analysis for crime reduction: Cure or Diagnosis? *Journal of Contemporary Criminal Justice, 30*(2), 147–168.
Santos, R. G., & Santos, R. B. (2015a). An ex post facto evaluation of tactical police response in residential theft from vehicle micro-time hot spots. *Journal of Quantitative Criminology*. doi:10.1007/s10940-015-9248-7.
Santos, R. G., & Santos, R. B. (2015b). Practice-based research: Ex post facto evaluation of evidence-based police practices implemented in residential burglary micro-time hot spots. *Evaluation Review*. doi:10.1177/0193841X15602818.
Santos, R. G., & Santos, R. B. (2015c). Evidence-based policing, "What works" and stratified policing, "How to make it work". *Translational Criminology, 8*, 20–22.
Santos, R. B., & Taylor, B. (2014). The integration of crime analysis into police patrol work: Results from a national survey of law enforcement. *Policing: An International Journal of Police Strategies and Management, 37*, 501–520.
Telep, C., Mitchell, R., & Weisburd, D. (2014). How much time should the police spend at crime hot spots? Answers from a police agency directed randomized field trial in Sacramento, California. *Justice Quarterly, 31*, 905–933.
Telep, C., & Weisburd, D. (2012). What is known about the effectiveness police practices in reducing crime and disorder?. *Police Quarterly, 15*, 331–357.
Tompson, L., & Bowers, K. (2012). A stab in the dark? A research note on temporal pattern of street robbery. *Journal of Research in Crime and Delinquency, 50*, 616–631.
Townsley, M., Homel, R., & Chaseling, J. (2003). Infectious burglaries: A test of the near repeat hypothesis. *British Journal of Criminology, 43*, 615–633.
Weisburd, D., Groff, E. R., & Yang, S.-M. (2012). *The criminology of place: Street segments and our understanding of the crime problem*. New York, NY: Oxford University Press.
Weisburd, D., Telep, C. W., Hinkle, J. C., & Eck, J. (2010). Is problem-oriented policing effective in reducing crime and disorder? Findings from a Campbell sys-tematic review. *Criminology & Public Policy, 9*(1), 139–172.